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Indian Standard

HYDRAULIC FLUID POWER — COMPATIBILITY BETWEEN ELASTOMERIC MATERIALS AND FLUIDS

ICS 23.100.01

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Price Group 7

Basic Fluid Power Sectional Committee, BP 14

NATIONAL FOREWORD

This Indian Standard which is identical with ISO 6072 : 1986 'Hydraulic fluid power — Compatibility between elastomeric materials and fluids' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Basic Fluid Power Sectional Committee and approval of the Basic and Production Engineering Division Council.

The text of the ISO Standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 37 : 1994 Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties	IS 3400 (Part 1) : 1987 Methods of test for vulcanized rubbers: Part 1 Tensile stress-strain properties (*second revision*)	Technically Equivalent
ISO 48 : 1994 Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 and 100 IRHD)	IS 3400 (Part 2) : 1995 Methods of test for vulcanized rubbers: Part 2 Hardness (*second revision*)	do
ISO 289 : 1994 Rubber, unvulcanized — Determination of Mooney viscosity	IS 3660 (Part 3) : 1988 Methods of test for natural rubber: Part 7 Determination of Mooney viscosity (*second revision*)	do
ISO 815 : 1991 Rubber, vulcanized or thermoplastic — Determination of compression set at ambient, elevated or low temperatures	IS 3400 (Part 10) : 1977 Methods of test for vulcanized rubbers: Part 10 Compression set at constant strain (*first revision*)	do
ISO 1629 : 1995 Rubber and latices — Nomenclature	IS 6611 : 1988 Symbols for rubbers and latices (*first revision*)	do
ISO 1817 : 1985 Rubber, vulcanized — Determination of the effect of liquids	IS 3400 (Part 6) : 1983 Methods of test for vulcanized rubbers : Part 6 Resistance to liquids (*first revision*)	do
ISO 2781 : 1988 Rubber, vulcanized — Determination of density	IS 3400 (Part 9) : 1978 Methods of test for vulcanized rubbers: Part 9 Density (*first revision*)	do
ISO 5598 : 1985 Fluid power systems and components — Vocabulary	IS 10416 : 1992 Fluid power systems and components — Vocabulary (*first revision*)	Identical

(*Continued on third cover*)

Indian Standard

HYDRAULIC FLUID POWER — COMPATIBILITY BETWEEN ELASTOMERIC MATERIALS AND FLUIDS

0 Introduction

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. Elastomers are used as seals in fluid power systems. Elastomeric materials are any substances having the ability to return to original size and shape after deformation. Hydraulic fluids are water, oil or other fluids which are forced through an orifice or an enclosed circuit. Elastomeric materials and hydraulic fluids are compatible if they are not altered by chemical interaction.

Annex A to this International Standard specifies the percentage volume change of commercial rubbers in mineral-based oils. Annex B describes the rapid method for indicating the effect of mineral-based oils on elastomers by measurement of volume change index (VCI). Annex C provides an information report.

1 Scope and field of application

This International Standard provides formulations, mixing and vulcanization procedures for three types of elastomeric compositions:

a) acrylonitrile-butadiene rubber (NBR 1);

b) fluoroelastomers (FPM 1);

c) ethylene propylene diene rubber (EPDM 1).

These procedures evaluate the effect of mineral-based and fire-resistant hydraulic fluids upon such compositions by measurement, under controlled conditions, of physical properties of standard test pieces of the suitable test elastomer before and after immersion in the fluids.

The elastomeric materials used in these formulations are sensitive to fluid variations and have comparatively high swelling characteristics. Stable cure systems should be used to give adequate storage life.

NOTE — This International Standard does not provide formulations of elastomeric materials for actual service.

The changes in volume, hardness, tensile strength and elongation at break [which standard test specimens of the suitable standard test elastomer undergo when immersed in a certain fluid under specified test conditions (see table 7)] establish an elastomer compatibility index (ECI) for this fluid, which can be expressed in the format given in clause 5.

The ECI (which should be quoted by oil suppliers) allows selection of suitable combinations of fluids and elastomeric materials without prolonged testing. In the case of mineral-based oils, it will be possible to predict the percentage volume change of commercial rubbers (see annex A).

NOTE — The ECI may provide enough information so as to eliminate totally unsuitable elastomer/fluid combinations without having to resort to extensive screening tests.

Representative standard compositions of various types of elastomers permit evaluation of the effect of hydraulic fluids on such compositions and comparison with commercial elastomeric materials for actual service.

They would also assist producers of additives and hydraulic fluids in the development of hydraulic fluids compatible with different elastomer types.

2 References

ISO 37, *Rubber, vulcanized — Determination of tensile stress-strain properties.*

ISO 48, *Vulcanized rubbers — Determination of hardness (Hardness between* 30 *and* 85 IRHD*).*

ISO 289, *Rubber, unvulcanized — Determination of Mooney viscosity.*

ISO 815, *Rubber, vulcanized — Determination of compression set at normal and at high temperatures.*[1]

ISO 1629, *Rubber and latices — Nomenclature.*

ISO 1817, *Rubber, vulcanized — Determination of the effect of liquids.*

ISO 2393, *Rubber test mixes — Preparation, mixing and vulcanization — Equipment and procedures.*

ISO 2781, *Vulcanized rubbers — Determination of density.*

ISO 5598, *Fluid power systems and components — Vocabulary.*

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[1] At present at the stage of draft. (Revision of ISO 815-1972.)

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 5598 and the following definitions apply.

NOTE — For definitions of the types of fluids involved, see table 7.

3.1 elastomer: A macromolecular, rubber-like material that returns rapidly to approximately its initial dimensions and shape after substantial deformation by a weak stress and release of the stress.

3.2 test elastomer: A rubber vulcanizate with a known composition, used for evaluating the effect of media on elastomers. In order to minimize error a test elastomer contains only the most essential ingredients for a vulcanizate.

3.3 commercial rubber: An elastomeric material for actual service the composition of which is not given by the manufacturer and which contains many more ingredients than the standard rubbers in order to fulfil processing and service requirements.

NOTE — It is not advisable to use commercial rubbers for quality control of media as they are generally subject to larger quality tolerances than test elastomers.

4 Test elastomers

4.1 Recommended practice

4.1.1 The mixing and vulcanization procedures for these test elastomers as laid down in ISO 2393 shall be followed.

4.1.2 A single source for each of the ingredients of the test elastomers shall be used and the quality of each batch produced shall be checked.

4.2 Standard acrylonitrile-butadiene rubber (NBR 1)

4.2.1 Composition by mass

The composition by mass is given in table 1.

Table 1 — Composition by mass of standard acrylonitrile-butadiene rubber (NBR 1)

Material	Parts by mass
NBR [1)]	100,0
Zinc oxide (rubber grade)	5,0
Polymerized 2,2,4-trimethyl 1,2-dihydroquinoline (melting point 75 to 100 °C)	0,5
FEF carbon black (ASTM designation: N 550)	70,0
Dicumyl peroxide (grade with 40 % peroxide content on inert filler)	3,0
Total	178,5

1) Acrylonitrile content 28 ± 1 %, cold polymerized, Mooney viscosity (see ISO 289): 45 ± 5 ML (1 + 4) 100 °C.

4.2.2 Mixing procedure

Proceed as follows, maintaining the surface temperature of the rolls at 50 ± 5 °C.

4.2.2.1 Band crude rubber with the mill opening set at 1,4 mm and break down.

4.2.2.2 Add the zinc oxide, then the polymerized 2,2,4-trimethyl 1,2-dihydroquinoline evenly across the rolls at a constant rate.

4.2.2.3 Make 3/4 cuts on the rolls from one end diagonally to the other end.

4.2.2.4 Add approximately half the carbon black evenly across the rolls at a constant rate.

4.2.2.5 Open the mill at intervals to maintain a constant bank.

4.2.2.6 Make three 3/4 cuts from each side.

4.2.2.7 Add the rest of the carbon black, including all the pigment that has dropped through to the pan.

4.2.2.8 Add the dicumyl peroxide evenly across the rolls.

4.2.2.9 Make six 3/4 cuts from each side.

4.2.2.10 Cut the batch from the mill and set the opening to 0,2 mm.

4.2.2.11 Pass the rolled stock endwise through the mill six times.

4.2.2.12 Sheet off samples at 2,2 mm and allow to cool on flat metal surface.

4.2.2.13 Prepare samples for cure.

4.2.3 Preparation of standard vulcanized sheets

Cure standard vulcanized sheets 2 ± 0,2 mm thick for 20 min at 170 °C.

4.2.4 Control tests

Carry out all the tests specified in table 2 on sheets 2 ± 0,2 mm thick.

Table 2 — Control tests for NBR 1

Control tests	Property requirement	Unit	Document specifying test method
Hardness	80 ± 3	IRHD (micro-test)	ISO 48
Tensile strength, dumb-bell type 2, min.	20	MPa 1)	ISO 37
Elongation at break, dumb-bell type 2, min.	150	%	ISO 37
Compression set, after 22 h at 100 °C, using type B test piece obtained by plying three discs, max.	20	%	ISO 815
Density	1,23 ± 0,01	Mg/m^3	ISO 2781
Percentage change in mass, after 22 h immersion at 23 ± 2 °C in ISO liquid B [70 % (*V*/*V*) pure 2,2,4-trimethylpentane and 30 % (*V*/*V*) pure toluene]	27 ± 2	%	ISO 1817

1) 1 MPa = 10^6 Pa; 1 Pa = 1 N/m^2

4.3 Standard fluoroelastomer (FPM 1) (vinylidene fluoride hexafluoropropylene copolymer)

4.3.1 Composition by mass

The composition by mass is given in table 3.

Table 3 — Composition by mass of standard fluoroelastomer (FPM 1)

Material	Parts by mass
Vinylidene fluoride hexafluoropropylene copolymer 1)	100,0
Magnesium oxide 2)	20,0
MT carbon black (ASTM designation: N 990)	20,0
N,N'-dicinnamylidene-1,6 hexane diamine	3,0
Total	143,0

1) Mooney viscosity: 65 ± 7 ML (1 + 10) 100 °C.

2) The grade of the magnesium oxide to be used is specified in the standard formula for the fluoroelastomer compound given in ASTM D 2934-1975 (Reapproved 1983), *Rubber seals — Compatibility with service fluids.*

4.3.2 Mixing procedure

Proceed as follows, maintaining the surface temperature of the rolls at 50 ± 5 °C.

4.3.2.1 Band the crude rubber with the mill opening set at 1,4 mm.

4.3.2.2 Blend carbon black, magnesium oxide and *N,N'*-dicinnamylidene-1,6 hexane diamine together and add evenly across the rolls at a constant rate.

4.3.2.3 Open the mill at intervals to maintain a constant bank.

4.3.2.4 When all the pigment has been added, including any that has dropped through to the pan, make one 3/4 cut from each side.

4.3.2.5 Make three 3/4 cuts from each side.

4.3.2.6 Cut the batch from the mill and set the opening to 0,2 mm.

4.3.2.7 Pass the rolled stock endwise through the mill six times.

4.3.2.8 Sheet off samples at 2,2 mm and allow to cool on a flat metal surface for 24 h.

4.3.2.9 Refine mixed stock after 24 h of ageing by passing it six times through a tightly set mill (opening set at 0,8 mm) with a surface temperature of the rolls of 40 ± 5 °C.

4.3.2.10 Sheet off at 2,2 mm and allow to cool on a flat metal surface.

4.3.2.11 Prepare samples for cure.

4.3.3 Preparation of standard vulcanized sheets

Mould-cure standard vulcanized sheets 2 ± 0,2 mm thick for 20 min at 170 °C and post-cure them for 24 h at 200 °C in an air-circulating oven.

4.3.4 Control tests

Carry out all the tests specified in table 4 on sheets 2 ± 0,2 mm thick.

Table 4 — Control tests for FPM 1

Control tests	Property requirement	Unit	Document specifying test method
Hardness	75 ± 3	IRHD (micro-test)	ISO 48
Tensile strength, dumb-bell type 2, min.	13	MPa	ISO 37
Elongation at break, dumb-bell type 2, min.	200	%	ISO 37
Compression set, after 22 h at 150 °C, using type B test piece obtained by plying three discs, max.	30	%	ISO 815
Density	1,92 ± 0,02	Mg/m^3	ISO 2781
Percentage change in mass, after 22 h immersion at 23 ± 2 °C in ISO liquid E [100 % (*V*/*V*) toluene]	2 to 5	%	ISO 1817

4.4 Standard ethylene propylene diene rubber (EPDM 1)

4.4.1 Composition by mass

The composition by mass is given in table 5.

Table 5 — Composition by mass of standard ethylene propylene diene rubber (EPDM 1)

Material	Parts by mass
Ethylene propylene diene terpolymer[1]	100,0
FEF carbon black (ASTM designation: N 550)	50,0
Zinc oxide (rubber grade)	5,0
Polymerized 2,2,4-trimethyl 1,2-dihydroquinoline (melting point 75 to 100 °C)	0,5
Dicumyl peroxide (grade with 40 % peroxide content on inert filler)	5,0
Total	160,5

[1] Mooney viscosity: 40 ± 5 ML (1 + 8) 100 °C.

4.4.2 Mixing procedure

Proceed as follows, maintaining the surface temperature of the rolls at 50 ± 5 °C.

4.4.2.1 Band the crude rubber with the mill opening set at 1,4 mm and break down.

4.4.2.2 Blend carbon black, zinc oxide and the polymerized 2,2,4-trimethyl 1,2-dihydroquinoline together and add them evenly across the rolls at a constant rate.

4.4.2.3 Open the mill at intervals to maintain a constant bank.

4.4.2.4 When all the pigment has been added, including any that has dropped through to the pan, make one 3/4 cut from each side.

4.4.2.5 Add the dicumyl peroxide evenly across the rolls.

4.4.2.6 When the dicumyl peroxide has been mixed in, make three 3/4 cuts from each side.

4.4.2.7 Cut the batch from the mill and set the opening to 0,8 mm.

4.4.2.8 Pass the rolled stock endwise through the mill six times.

4.4.2.9 Sheet off samples at 2,2 mm and allow to cool on a flat metal surface.

4.4.2.10 Prepare samples for cure.

4.4.3 Preparation of standard vulcanized sheets

Cure standard vulcanized sheets 2 ± 0,2 mm thick for 20 min at 170 °C.

4.4.4 Control tests

Carry out all the tests specified in table 6 on sheets 2 ± 0,2 mm thick.

Table 6 — Control tests for EPDM 1

Control tests	Property requirement	Unit	Document specifying test method
Hardness	68 ± 3	IRHD (micro-test)	ISO 48
Tensile strength, dumb-bell type 2, min.	15	MPa	ISO 37
Elongation at break, dumb-bell type 2, min.	200	%	ISO 37
Compression set, after 22 h at 150 °C, using type B test piece obtained by plying three discs, max.	25	%	ISO 815
Density	1,08 ± 0,01	Mg/m^3	ISO 2781
Percentage change in mass, after 22 h immersion at 23 ± 2 °C in methyl ethyl ketone	8 to 10	%	ISO 1817

5 Determination of elastomer compatibility index (ECI)

For the purposes of this International Standard, the elastomer compatibility index (ECI) shall be expressed as a simple one-line symbolic designation incorporating the following details:

a) the test elastomer used;

b) the percentage change in volume, see 5.2;

c) the change in hardness, expressed in IHRD (micro-test), see 5.3;

d) the percentage change in tensile strength, see 5.4;

e) the percentage change in elongation at break, see 5.4.

5.1 Test conditions

Unless otherwise specified, refer to table 7 for test temperature and duration.

Table 7 — Test conditions for determination of elastomer compatibility index (ECI)

Fluid	Suitable test elastomer	Temperature °C ±2	Duration of test h ±2
Mineral-based oils	NBR 1 FPM 1	100	168
Water polyglycol solutions	NBR 1 EPDM 1 FPM 1	60	168[1)]
Oil-in-water emulsions	NBR 1 FPM 1	60	168[1)]
Water-in-oil emulsions	NBR 1 FPM 1	60	168[1)]
Halogenated hydrocarbons	FPM 1	100	168
Phosphate esters	EPDM 1 FPM 1[2)]	100	168

1) The test shall last 168 h, but equilibrium may not be achieved in these fluids.

2) FPM is not suitable for use with alkyl phosphate esters.

5.2 Determination of percentage change in volume

5.2.1 Test apparatus

5.2.1.1 Analytical balance, having a sensitivity of 0,1 mg, fitted with a nylon filament and a beaker containing distilled water placed on a bridge as shown in figure 1.

5.2.1.2 Stoppered glass jar, of dimensions such that the test pieces (see 5.2.2) remain completely immersed in the fluid being tested and are free to swell without restraint or distortion.

NOTE — The diameter of the mouth should allow free entry and exit of the specimens.

5.2.1.3 Fan-assisted, air-circulating oven, capable of maintaining a temperature to within ±2 °C.

5.2.2 Test pieces

Cut test pieces from sheets with a uniform thickness of 2 ± 0,2 mm so that they have either a rectangular shape (50 ± 1 mm) × (25 ± 1 mm) or a circular shape (ϕ 36 ± 1 mm).

NOTE — Both shapes give approximately the same results.

5.2.3 Procedure

5.2.3.1 Use three marked test pieces. Weigh each piece in air to the nearest milligram (mass m_1), and then reweigh each piece in distilled water at the standard laboratory temperature (mass m_2).

5.2.3.2 Take care to ensure that all air bubbles are removed.

NOTE — Formation of bubbles may be avoided by dipping the test piece momentarily into a liquid such as methyl alcohol.

5.2.3.3 Blot the test pieces dry with filter paper or a piece of textile fabric that does not deposit lint.

5.2.3.4 Immerse the rubber test pieces separately in the glass jar (5.2.1.2) containing a volume of the test fluid that is at least 15 times the combined volume of the test pieces and sufficient to keep the pieces totally immersed.

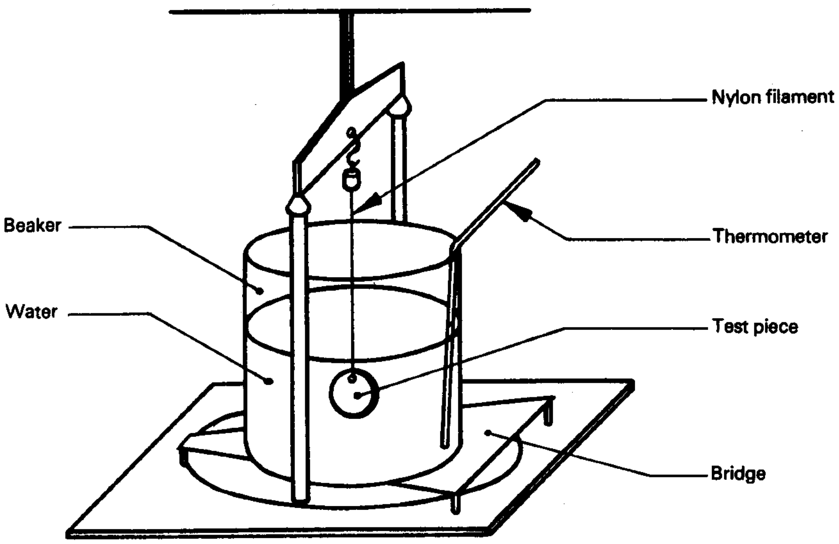


Figure 1 — Analytical balance for weighing in air and water

5.2.3.5 Replace the stopper and put the jar and its contents into the test oven (5.2.1.3).

NOTE — The test time and temperature, which depend on the nature of the fluid and the test elastomer, are given in table 7.

5.2.3.6 At the end of the immersion period, bring the jar and its contents to the standard laboratory temperature.

5.2.3.7 Remove any surplus fluid from the surface of the test piece.

NOTE — When removing non-aqueous fluids, dip each test piece momentarily in a suitable volatile liquid, such as petrol ether, and quickly wipe with filter paper or a lint-free piece of textile fabric.

5.2.3.8 Immediately place the test piece in a tared and stoppered weighing bottle and determine its mass in air (mass m_3) to the nearest milligram.

5.2.3.9 Remove the test piece from the bottle and immediately weigh it in distilled water (mass m_4) at the standard laboratory temperature.

5.2.4 Expression of results

The percentage change in volume, ΔV_{100}, is given by the formula

$$\Delta V_{100} = \frac{(m_3 - m_4) - (m_1 - m_2)}{(m_1 - m_2)} \times 100$$

where

m_1 is the initial mass of the test piece in air;

m_2 is the initial apparent mass of the test piece in water;

m_3 is the mass of the test piece in air after immersion;

m_4 is the apparent mass of the test piece in water after immersion.

Take the arithmetic mean of the measurements obtained for the three test pieces.

NOTE — Data on the precision of results will be available after concluding the correlation work.

5.3 Determination of change in hardness

5.3.1 Test apparatus

5.3.1.1 Apparatus for measuring hardness, as described in ISO 48 (micro-test).

5.3.1.2 Stoppered glass jar, as described in 5.2.1.2.

5.3.1.3 Test oven, as described in 5.2.1.3.

5.3.2 Test pieces

Use the same three test pieces used for determination of percentage change in volume (see 5.2.2).

5.3.3 Procedure

5.3.3.1 Measure the hardness of the three test pieces at standard laboratory temperature (as described in ISO 48).

5.3.3.2 Immerse the test pieces in the immersion fluid (see 5.2.3.4 and 5.2.3.5).

5.3.3.3 At the end of the immersion period, bring the jar and its contents to the standard laboratory temperature.

5.3.3.4 Remove any surplus fluid from the surface of the test pieces (see 5.2.3.7).

5.3.3.5 Remeasure the hardness as described in ISO 48.

5.3.4 Expression of results

5.3.4.1 Take three hardness readings at different points on the test piece before and after immersion, and then record the median value.

5.3.4.2 Record the change in hardness in IRHD as described in ISO 48.

NOTES

1 If the apparatus for the micro-test is not available, it is permissible to measure Shore A hardness with three plied test pieces, bearing in mind that the results obtained may not agree with those measured on a one-piece specimen using the micro-test. In this case, indicate the change in hardness in Shore A in the test report.

2 Data on the precision of results will be available after concluding the correlation work.

5.4 Determination of percentage change in tensile strength and elongation at break

5.4.1 Test apparatus

5.4.1.1 **Tensile test apparatus,** as described in ISO 37.

5.4.1.2 **Stoppered glass jar,** as described in 5.2.1.2.

5.4.1.3 **Test oven,** as described in 5.2.1.3.

5.4.2 Test pieces

5.4.2.1 Use a dumb-bell type 2 as described in ISO 37.

5.4.2.2 For the purposes of comparison, carry out the tests on six immersed and six unimmersed test pieces.

5.4.3 Procedure

5.4.3.1 Mark the test pieces and measure the cross-section of each test piece, as described in ISO 37.

5.4.3.2 Immerse six test pieces in the immersion liquid (see 5.2.3.4 and 5.2.3.5).

5.4.3.3 At the end of the immersion period, bring the jar and its contents to standard laboratory temperature.

5.4.3.4 Remove any surplus fluid from the surface of the test pieces (see 5.2.3.7).

5.4.3.5 Measure the tensile strength, expressed in megapascals, and the percentage of elongation at break of the immersed and unimmersed pieces, as described in ISO 37.

5.4.4 Expression of results

5.4.4.1 Calculate the tensile strength per unit area of the original cross-section of the test piece before immersion.

5.4.4.2 Record the change expressed as a percentage of the value for unimmersed material.

The percentage change in tensile strength, ΔT_{100}, is given by the formula

$$\Delta T_{100} = \frac{T_2 - T_1}{T_1} \times 100$$

where

T_1 is the arithmetic mean of six measurements of tensile strength of unimmersed material, expressed in megapascals;

T_2 is the arithmetic mean of six measurements of tensile strength of immersed material, expressed in megapascals.

The percentage change of elongation at break, ΔL_{100}, is given by the formula

$$\Delta L_{100} = \frac{L_2 - L_1}{L_1} \times 100$$

where

L_1 is the arithmetic mean of six measurements of elongation at break of unimmersed material, expressed in millimetres;

L_2 is the arithmetic mean of six measurements of elongation at break of immersed material, expressed in millimetres.

NOTE — Data on the precision of results will be available after concluding the correlation work.

5.5 Test report

The elastomer compatibility index (ECI) for the fluid concerned shall be stated in the test report.

In addition to the ECI, the following information shall be included in the test report:

a) the type of fluid (e.g. mineral-based oil, phosphate ester, oil-in-water emulsion, etc.);

b) the test temperature and duration of test, if different from those values given in table 7;

c) any discolouration of the immersion liquid or formation of sediment;

d) the appearance of the test piece (e.g. cracks, stickiness, etc.).

6 Identification statement (Reference to this International Standard)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard:

"Elastomeric material compatibility with fluids determined in accordance with ISO 6072, *Hydraulic fluid power — Compatibility between elastomeric materials and fluids.*"

Annex A

Prediction of percentage change in volume of commercial rubbers in mineral-based oils

(This annex forms an integral part of the standard.)

A.0 Introduction

There is an approximate linear relationship between the equilibrium percentage changes in volume of nitrile rubber in a number of mineral-based oils and those of another nitrile rubber in the same oils. In other words, if the equilibrium percentage changes in volume of different commercial nitrile rubbers in different mineral oils were to be plotted against those of standard acrylonitrile-butadiene rubber NBR 1 (see 4.2 and table 1) in the same oils, a linear relationship would be obtained as shown in figure 2, even at temperatures other than the standard.

This relationship applies not only to nitrile rubbers, but also to other oil-resistant elastomers, e.g. ACM and FPM rubbers.

A.1 Scope and field of application

This annex specifies a method for predicting the percentage change in volume of commercial rubbers in mineral-based oils. The percentage change in volume of a standard elastomer NBR 1, after immersion in various mineral-based oils under the test conditions given in table 7, establishes a quick method for predicting percentage changes in volume of commercial rubbers in the same oils, without having to carry out tests on each combination.

A.2 Definition

swelling behaviour (SB) of commercial rubbers: The correlation of percentage changes in volume in a range of mineral oils with those of a standard elastomer NBR 1 (see figure 2).

A.3 Procedure

If seal manufacturers quote the swelling behaviour (SB) of their rubbers graphically (see figure 2) and, at the same time, the oil suppliers quote percentage changes in volume of NBR 1 in their oils, interested parties would be able to predict volume changes of those commercial rubbers in those oils.

Example:

If the percentage change in volume of a standard elastomer NBR 1 (after immersion in mineral oil) is equal to a (see figure 2), it would be possible to predict percentage changes in volume equal to b, c and d for commercial rubbers Nos. 1, 2 and 3, respectively, without having to carry out immersion tests in this oil.

NOTE — Data on the precision of results will be available after concluding the correlation work.

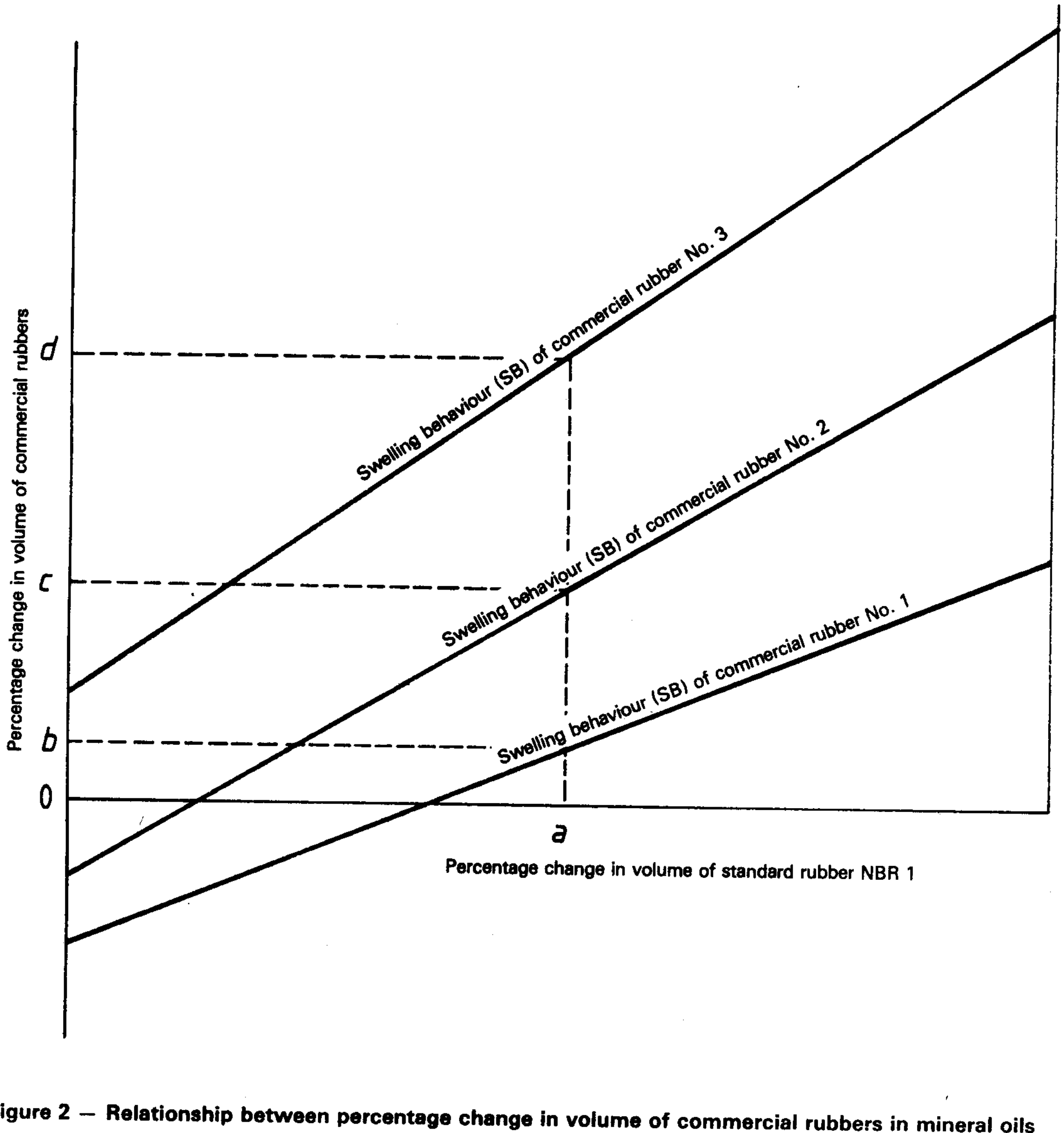


Figure 2 — Relationship between percentage change in volume of commercial rubbers in mineral oils and of standard rubber NBR 1

Annex B

Rapid method for indicating the effect of mineral-based oils on elastomers by measuring volume change index (VCI)

(This annex form an integral part of the standard.)

B.1 Introduction

Another method for determining the effect of mineral-based oils is by measuring the volume change index (VCI). The VCI, obtained using the rapid method, may differ from the percentage change in volume obtained using the detailed method (see 5.2). However, ranking the results by either method is the same.

B.2 Scope and field of application

This annex specifies a method which establishes a simple and rapid means of indicating the effect of mineral-based oils on elastomers by measuring the change in volume of a standard test ring after the 22 h immersion test. The method is considered more reliable than the aniline point, as it has been confirmed that oils of similar aniline point can differ significantly in their swelling power. The method is only applicable to mineral-type fluids and can be used for purposes where rapidity and ease of measurement are more important than accuracy, i.e. quality control. It is particularly suitable for hydraulic equipment manufacturers with limited laboratory facilities to safeguard themselves against faulty batches of oil.

B.3 Test elastomer

Standard acrylonitrile-butadiene rubber NBR 1 (see 4.2 and table 1) shall be used.

B.4 Control tests

Carry out the control tests on sheets 2 ± 0,2 mm thick, moulded at 170 °C from the same mix as that from which the test specimens are manufactured (see 4.2.3, 4.2.4 and table 2).

B.5 Procedure

B.5.1 Use as a test piece a standard ring[1] having an internal diameter of 25 ± 0,25 mm with a cross-section of 1,5 ± 0,15 mm square.

B.5.2 Measure the internal diameter before immersion (record this measurement as d_1) and again after immersion for 22 h in 50 to 55 ml of the oil at 100 °C (record this measurement as d_2)[2], using a tapered gauge[3] to ensure that no clearance is visible between the inside of the ring and the gauge.

B.5.3 Record the internal diameter to the nearest 0,025 mm (1/4 division) observed at the lower edge of the ring.

B.5.4 Calculate the percentage linear swell (SD) by using the following formula

$$\mathrm{SD} = \frac{d_2 - d_1}{d_1} \times 100$$

where

d_1 is the internal diameter measured before immersion for 22 h;

d_2 is the internal diameter measured after immersion for 22 h.

B.5.5 Use a conversion table (see table 8) to convert the percentage linear swell (SD) into the percentage volumetric change (SV)[4].

B.5.6 Express the results in terms of the volume change index (VCI)[5].

B.6 Precision of results

B.6.1 Repeatability

The repeatability for this rapid method is given by

$$0{,}62\ \sqrt[3]{A}$$

or, alternatively,

$$\sqrt[3]{0{,}238A}$$

where A is the mean.

---

[1] Standard rings are available commercially; details may be obtained from the ISO Central Secretariat.

[2] See 5.2.

[3] The tapered gauge shall be manufactured from stainless steel or brass and shall comply with the requirements of figure 3.

[4] See table 4.

[5] Defined as the percentage volumetric change (SV) expressed to the nearest whole number.

NOTES

1 Oils are in the range from 1 to 35 VCI.

2 Duplicate results achieved by the same operator should not be considered incorrect unless they differ by more than the appropriate value.

B.6.2 Reproducibility

The reproducibility for this rapid method is given by

$$1{,}0\ \sqrt[3]{A}$$

or, alternatively,

$$\sqrt[3]{A}$$

where A is the mean.

NOTES

1 Oils are in the range from 1 to 35 VCI.

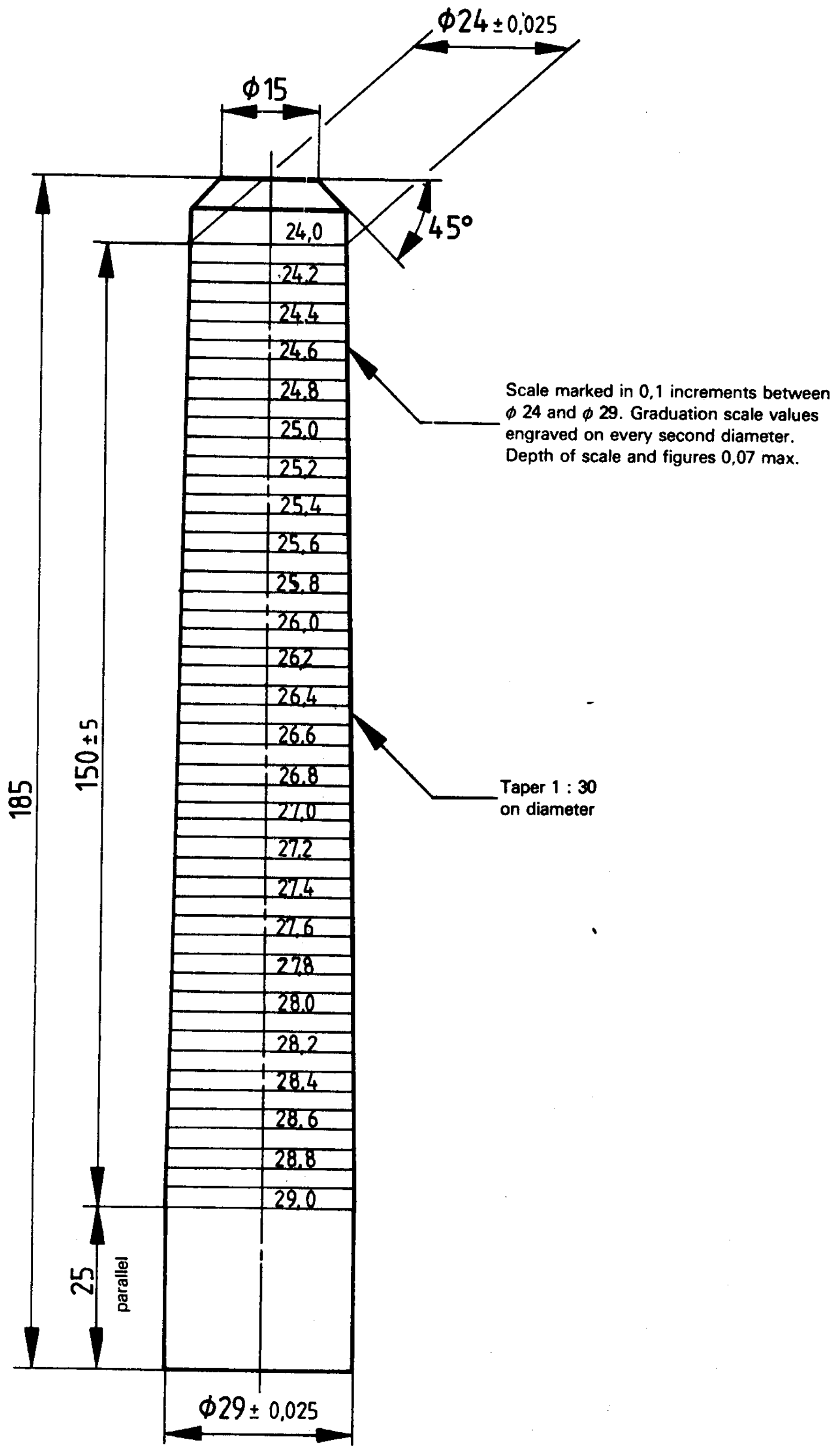
2 Results submitted by each of two laboratories should not be considered incorrect unless they differ by more than the appropriate value.

Table 8 — Conversion table for converting percentage linear swell (SD) into percentage volumetric change (SV)
[The volume change index (VCI) is the percentage volumetric change (SV) expressed to the nearest whole number.]

Values in percentages

SD	SV	SD	SV	SD	SV
0,1	0,30	5,1	16,09	10,1	33,46
0,2	0,60	5,2	16,43	10,2	33,83
0,3	0,90	5,3	16,76	10,3	34,19
0,4	1,20	5,4	17,09	10,4	34,56
0,5	1,51	5,5	17,42	10,5	34,92
0,6	1,81	5,6	17,76	10,6	35,29
0,7	2,11	5,7	18,09	10,7	35,66
0,8	2,42	5,8	18,43	10,8	36,03
0,9	2,72	5,9	18,76	10,9	36,39
1,0	3,03	6,0	19,10	11,0	36,76
1,1	3,34	6,1	19,44	11,1	37,13
1,2	3,64	6,2	19,78	11,2	37,50
1,3	3,95	6,3	20,12	11,3	37,87
1,4	4,26	6,4	20,46	11,4	38,25
1,5	4,57	6,5	20,79	11,5	38,62
1,6	4,88	6,6	21,14	11,6	38,99
1,7	5,19	6,7	21,48	11,7	39,37
1,8	5,49	6,8	21,82	11,8	39,74
1,9	5,81	6,9	22,16	11,9	40,12
2,0	6,12	7,0	22,51	12,0	40,49
2,1	6,43	7,1	22,86	12,1	40,87
2,2	6,75	7,2	23,19	12,2	41,28
2,3	7,06	7,3	23,54	12,3	41,62
2,4	7,37	7,4	23,88	12,4	42,00
2,5	7,69	7,5	24,23	12,5	42,38
2,6	8,00	7,6	24,58	12,6	42,76
2,7	8,32	7,7	24,92	12,7	43,14
2,8	8,64	7,8	25,27	12,8	43,52
2,9	8,95	7,9	25,62	12,9	43,91
3,0	9,27	8,0	25,97	13,0	44,29
3,1	9,59	8,1	26,32	13,1	44,67
3,2	9,91	8,2	26,67	13,2	45,06
3,3	10,23	8,3	27,02	13,3	45,44
3,4	10,55	8,4	27,38	13,4	45,83
3,5	10,87	8,5	27,73	13,5	46,21
3,6	11,19	8,6	28,08	13,6	46,60
3,7	11,52	8,7	28,44	13,7	46,99
3,8	11,84	8,8	28,79	13,8	47,38
3,9	12,16	8,9	29,15	13,9	47,76
4,0	12,49	9,0	29,50	14,0	48,15
4,1	12,81	9,1	29,86	14,1	48,54
4,2	13,14	9,2	30,22	14,2	48,94
4,3	13,46	9,3	30,58	14,3	49,33
4,4	13,79	9,4	30,93	14,4	49,72
4,5	14,12	9,5	31,29	14,5	50,11
4,6	14,44	9,6	31,65	14,6	50,51
4,7	14,77	9,7	32,01	14,7	50,90
4,8	15,10	9,8	32,38	14,8	51,30
4,9	15,43	9,9	32,74	14,9	51,69
5,0	15,76	10,0	33,10	15,0	52,09

Dimensions in millimetres



Scale marked in 0,1 increments between ϕ 24 and ϕ 29. Graduation scale values engraved on every second diameter. Depth of scale and figures 0,07 max.

Taper 1 : 30 on diameter

Figure 3 — Tapered rod gauge

Annex C

Information report

(This annex does not form an integral part of the standard.)

C.1 Types of hydraulic fluids

Hydraulic fluids include mineral-based oils and fire-resistant fluids. The latter fall into two main groups:

a) **Aqueous based**

- oil-in-water emulsions
- water-in-oil emulsions
- water polyglycol solutions

b) **Non-aqueous based**

- phosphate esters
- halogenated hydrocarbons [usually based on polychlorinated biphenyls (PCBs)] [1]

C.2 Types of elastomers

A wide variety of elastomer types[2] are used in hydraulic equipment, for example:

- acrylonitrile-butadiene rubbers (NBR);
- fluorocarbon rubbers (FPM);
- ethylene propylene diene rubbers (EPDM);
- butyl rubbers (IIR);
- polyacrylic rubbers (ACM);
- silicone rubbers (VMQ);
- chloroprene rubbers (CR);
- polyurethanes (EU and AU).

NOTE — The names of the elastomeric materials are generic, i.e. a whole variety of compounds may exist under that name, all of which will have certain properties but specific properties differ with the degree of compounding.

C.2.1 Acrylonitrile-butadiene rubbers

C.2.1.1 Acrylonitrile-butadiene rubbers are the most important class of elastomers used in hydraulic equipment. They are resistant to petroleum oils, to fire-resistant oil-in-water and water-in-oil emulsions. However, they are not suited for use with phosphate ester fluids or halogenated hydrocarbons.

C.2.1.2 Chemically, acrylonitrile-butadiene rubber is a copolymer of butadiene and acrylonitrile, the acrylonitrile content varying between approximately 18 % and 48 %. Nominal designations are low, medium and high nitrile. Resistance to petroleum-based oils increases with increasing nitrile content, but, at the same time, low-temperature flexibility decreases with increasing nitrile content. In order to obtain good low-temperature performance with acrylonitrile-butadiene rubbers, it is usually necessary to sacrifice some high-temperature oil resistance.

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[1] Recently, the use of PCBs in hydraulic fluids (other than in mining) has been banned owing to their pollutive nature.

[2] The nomenclature and abbreviations used for elastomers are in accordance with ISO 1629.

C.2.2 Fluoroelastomers

C.2.2.1 Fluoroelastomers are based on copolymerization of vinylidene-fluoride and hexafluoropropylene, offering a range of rubbers with outstanding resistance to chemical attack and maximum continuous service temperature of 200 °C, although its low temperature performance is only comparable with that of high nitrile.

C.2.2.2 Fluoroelastomers are resistant to mineral-based oils, halogenated hydrocarbons and aryl phosphate ester fluids, but not resistant to alkyl phosphate esters.

C.2.3 Ethylene propylene diene rubbers

Ethylene propylene diene rubbers are not resistant to mineral-based oils nor halogenated hydrocarbons. They are mainly used in hydraulic systems based on fire-resistant phosphate ester fluids. They are also excellent for steam and hot water service.

C.3 Action of hydraulic fluids on elastomers

Elastomers in contact with hydraulic fluids are subject to two simultaneous actions:

a) absorption of the liquid by the rubber;

b) extraction of soluble constituents (especially plasticizers) from the rubber.

The result is a change of volume, i.e. a swelling if a) is greater than b) or shrinkage if b) is greater than a).

Swell increases with time of immersion up to a point where no more fluid will be absorbed and the volumetric expansion remains constant. Swell also depends on temperature: as a general rule, the higher the temperature, the greater will be the equilibrium expansion. The time for equilibrium swelling is proportional to the square of the thickness of the test piece.

The change in volume can alter the physical properties of the elastomer, such as hardness, tensile strength and extensibility. Furthermore, some additives in hydraulic fluids can react chemically with the elastomer, particularly at elevated temperatures, leading to major changes in the chemical and physical properties of the elastomeric material, such as embrittlement. These changes can considerably affect the performance of elastomers used in hydraulic systems.

(*Continued from second cover*)

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following ISO Standard and has decided that it is acceptable for use in conjunction with this standard:

ISO 2393 :1994	Rubber test mixes — Preparation, mixing and vulcanization — Equipment and procedures

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2:1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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